# Design of Advanced Reflectarrays and Their Application in Future Antenna Systems

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***Abstract*—In recent years, there have been significant interest in reflectarray antennas and the latest research have shown that reflectarrays can be used to provide solutions which are otherwise not possible using existing solutions. In this paper, we present a general design framework for the design of advanced reflectarrays and show how it can be used to design reflectarrays for applications for future antenna systems.**

***Index Terms*—reflectarrays, optimization, space applications**

## I. Introduction

In the last decade, research and development of reflectarrays have gained momentum and many advanced reflectarrays have been designed [1]. Despite this, reflectarrays have not yet gained widespread acceptance for space applications and conventional reflectors are still preferred. One of reasons is believed to be the lack of a dedicated design tool. Recent developments performed at TICRA have shown that the performance of the reflectarray can be greatly improved compared to previously reported results if appropriate design methods are considered [2]. For this reason, TICRA has in recent years been working on developing a general design framework for the design of reflectarrays and other quasi-periodic surfaces.

In this paper, the general design framework developed by TICRA is presented followed by application examples.

## II. General Design Framework

### *A. Design Procedure*

For the design of reflectarrays, the process used today is mostly based on tools with dedicated features for periodic surfaces. First, the type of array elements is designed based on its response in a periodic environment. Subsequently, a phase-only approach is adopted where the array elements are adjusted, element-by-element, to provide the phase distribution that is required over the reflectarray surface.

The main drawback with the phase-only approach is that it optimizes each element individually by considering the local phase response, which is an intermediate quantity. The actual antenna requirements are formulated in terms of the radiation pattern performance. As a consequence, the direct relation between the optimization variables and the optimization goals is not maintained, leading to suboptimal designs.

To circumvent this issue, a direct optimization approach where all array elements are optimized simultaneously to fulfil the pattern specifications shall be used. The fact that all elements are optimized simultaneously in a direct manner implies that a local mismatch between the desired and actual element performance can be compensated by all other elements.

The design procedure adopted in the general design framework is illustrated in Fig. 1. The initial two steps are identical to the existing design methods. The third step involves a large-scale direct optimization of all array elements simultaneously. As a final step, the array elements can be optimized together with the remaining part of the antenna system. This gives the possibility to optimize the reflectarray in their final operational environment by also allowing reflectors and other components to be included in the optimization.

For the analysis, it is essential that the analysis methods used during the optimization are both accurate and efficient. To this end, several analysis methods are included in the framework and should be used depending on the application at hand. The methods are based on the local periodicity assumption and have been specifically tailored to handle realistic configurations involving multiple panels, holes, and planar as well as curved surfaces. The analysis accuracy has been verified against full-wave simulations and various measurements campaigns.

For the optimization, we have developed an efficient algorithm that is well-suited for large-scale optimization problems. The algorithm is a gradient-based minimax algorithm that is also used in TICRA's commercial software packages.

## III. Applications

### *A. Contoured Beam Applications*

Reflectarrays provide a cheaper alternative solution for shaped reflectors which are currently the preferred technology for contoured beam applications. However, in order to match the performance of traditional shaped reflectors, curved reflectarrays are needed to enhance the bandwidth. We have shown that using a standard parabolic surface, the requirements of multiple missions in Ku-band are can covered by simply changing the reflectarray element pattern while maintaining performances comparable to shaped reflectors [3].

For lower frequencies, e.g., C-band, where the size of the reflectors needs to be $>3\,\mathrm{m}$, reflectarrays can be a viable solution. To this end, a reflectarray can be made up by combining several planar panels which can be tilted wrt. each other to emulate the surface of a shaped reflector. In [4], we designed a faceted reflectarray with a diameter of 6 m operating in C-band. It consists of nine planar panels which are tilted wrt. each other, see Fig. 2.

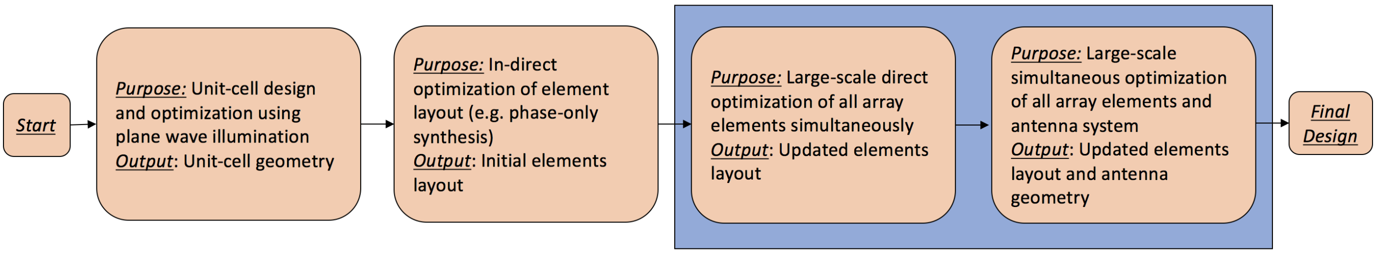


Fig. 1. Design procedure for the design of reflectarray. The steps in the blue box are unique capabilities introduced in the design framework.

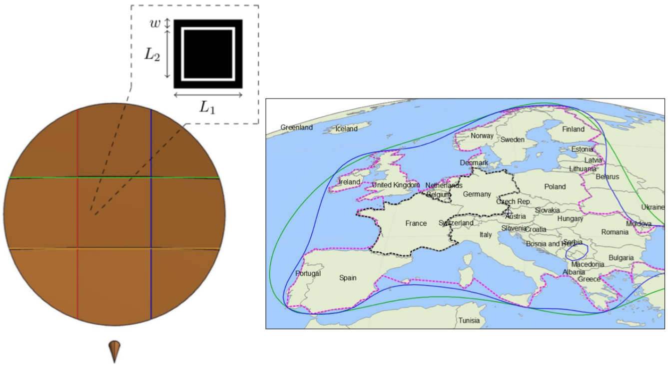


Fig. 2. C-band 6 m faceted reflectarray consisting of nine tilted panels and its radiation pattern compared to a 3 m shaped reflector.

### *B. Multiple Spot Beam Applications*

Multiple beam reflector antennas are becoming more and more popular for telecommunications applications due to their capability of delivering high capacity for high-throughput satellites. Currently, the state-of-the-art uses four single-feed-per-beam reflectors to cover a contiguous spot beam coverage following the 4-color reuse scheme. Using a parabolic reflectarray, it is possible to reduce the number of antennas from four to two following the concept presented in [5]. In an on-going ESA activity, TICRA has, together with MDA, Canada, designed and manufactured a doubly curved multiple spot beam reflectarray, the first of its kind, see Fig. 3. A perfect correlation between simulations and measurements was obtained, demonstrating the high accuracy of the design tool and the manufacturability of a curved reflectarray.

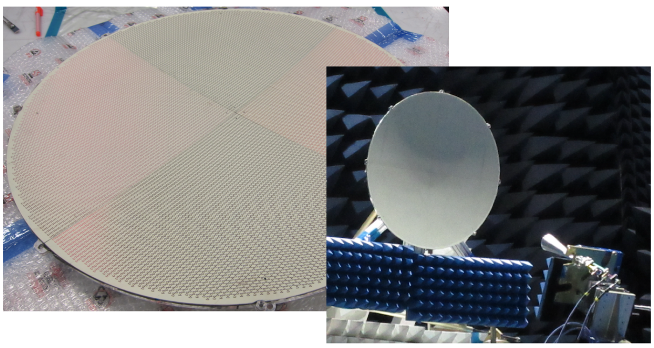

Fig. 3. Ka-band Tx/Rx curved multiple spot beam reflectarray.

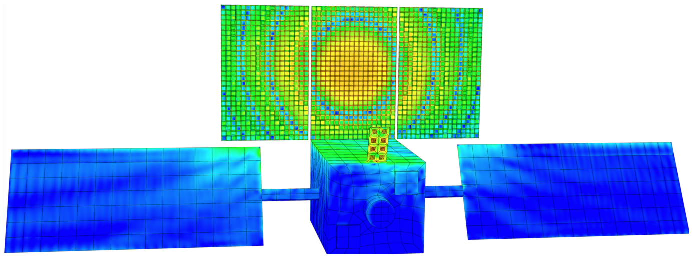

Fig. 4. Reflectarray model of ESA's M-ARGO CubeSat.

### *C. Small/CubeSats Applications*

Small satellites such as CubeSats have seen a significant growth over the past decade. For many CubeSat applications, high-gain antennas are needed, but due to the limited size/power of the CubeSats, this can be challenging. Deployable reflectarrays are ideal candidates on-board CubeSats due to their flat nature. Consequently, several space agencies, e.g., NASA and ESA, are working on reflectarrays for CubeSats and TICRA's design tool is being used in these work, see Fig. 4.

### *D. Earth Observation*

For earth observation missions that require high resolution SAR instruments, long and relatively narrow antennas are usually needed. In addition, the antenna structure must be stowed in order to fit to the volume available on current launchers. The reflectarray technology is a promising candidate to meet these requirements and both NASA and ESA have identified. Currently, TICRA is working together with Airbus Defence and Space on an ESA funded activity on this topic.

## References

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